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ABSTRACT

This study reports on the improvement of a teacher researcher's teaching practice by adopting a constructivist teaching approach. Four biology units on the nervous system, human circulatory system, evolution, and vertebrate classification were selected to illustrate a model of biology teaching. Data were drawn from student responses to teacher-designed, open-ended discussion questions based on the core concepts of each unit. Students were also surveyed about their attitudes and concepts toward this teaching approach. From the analysis, videotape transcripts, interview transcripts, teacher journals, and student journals, it was discovered that students show positive attitudes toward cooperative learning and their understanding of the nature of science increased significantly. (Contains 21 references.) (Author/DDR)

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The Effects of Restructuring Biology Teaching by a Constructivist Teaching Approach: An Action Research

(Multiple paper set: Studies on a Professional Development
Program for Secondary Science and Mathematics teachers
in Taiwan)

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ABSTRACT

The purpose of this study was to report the improvement of the teacher researcher's teaching practice by adopting a constructivist teaching approach. Four biology units: nerve system, human circulatory system, evolution, and vertebrate classification, were selected to illustrate a model of biology teaching.

The teacher designed open-ended discussion questions based on the core concepts of each unit. The students negotiated opinions within a group that followed with a presentation to raise whole class discussion issue. The teacher played as a facilitator to help students elaborate their concepts. The students were surveyed about their attitudes and concepts toward this teaching approach before, during and, after the teaching.

From the analysis of teaching materials, worksheets, surveys, videotape transcripts, interview transcripts, teacher journals, and student journals, it was discovered that students showed positive attitudes toward cooperative learning and, their understanding of the nature of science had increased significantly. However, students' prior concepts were not always changed effectively.

Key words: biology teaching, constructivist teaching approach, action research.

I. Introduction

The biology education in Taiwan had adopted mandatory textbooks, fixed scheduled progress, traditional lectures and an identical entrance examination for many years, especially in junior high school. Taiwanese teachers had little freedom to choose teaching material and making scheduled progress. A teacher who would like to provide supplementary materials or adopt an individualized instruction, should take a serious consideration on the scheduled progress. The teachers taught for the entrance examination in most of the school time. They emphasized repeated practice and memorization instead of promoting students' understanding of scientific concepts, thinking independently and critically, as well as their positive attitudes toward biology.

The proponents of constructivism and cooperative learning were on a different way. They sought after students' understanding of the history of scientific knowledge progress. They provided students opportunities to generate problems and solve them, rather than memorize facts and carry out cookbook type of laboratory activities. They aimed at students' understanding of the nature of science, being scientific literate, and holding a global world view.

Nowadays Taiwan has a series of educational reforms on the way. The publishers come into the textbook market. The teachers have more selections than before. The students have multiple ways besides the entrance examination to get into higher education system. The teachers are more encouraged in adopting various pedagogical instructions. These supported me to transform the teaching practice through the action research.

In this study, I developed a cooperative learning model for four selected topics: nerve system, human circulatory system, evolution, and classification scheme of vertebrates. The students were facilitated to construct their understanding of related science concepts.

The reason to choose these four topics is: the thematic topics in biological science include life, animal, plant,

human body, and continuity (Wandersee, Mintzes & Novak, 1995). These units were selected considering previous research findings and my ability in handling the topics.

This study intended to investigate the following research questions:

- (1) the students' attitude towards the constructivist pedagogical instructions in the four selected topics;
- (2) the differences between students' understandings of the nature of science before and after the instructions;
- (3) the students' understanding of related scientific concepts.

II. Theoretical framework

The cooperative learning within a group and competition among groups established the learning environment. The three principles suggested by Lin Sheng-chuan (1988) were followed for grouping students:

- (1) task structure: the students are grouped heterogeneously and cooperate to implement a task. The teacher assigns students roles, such as timekeeper, reporter, facilitator, inspector, observer, evaluator, and etc.
- (2) reward structure: the teacher encourages individual accountability and evaluates a group instead of an individual. The evaluation lists are written in positive terms.
- (3) authority structure: both individual and peer levels of control are suggested to establish and promote students learning. That is, the teacher gets rid of an authoritative controlling role.

The five elements of cooperative learning by Johnson and Johnson (1991) are emphasized. Those are:

- (1) Positive interdependence: It may be achieved by establishing mutual goals, joint rewards, divided resources, and complementary roles.
- (2) Face-to-face promotive interaction: The size of groups

needs to be small (from 2-6 members), as the perception that one's participation and efforts are needed increases as the size of the group decreases.

- (3) Individual accountability: Every member can not "hitchhike" on the work of others. Common ways to structure individual accountability include (a) giving an individual test to each student and (b) randomly selecting one student's product to represent the entire group.
- (4) Social skills: such as leadership, decision making, trust-building, efficient communication, and conflict-management skills.
- (5) Group processing: Group processing exists when group members discuss how well they are achieving their goals and maintaining effective working relationship.

According to Driver and Easley (1983), the students' conceptual frameworks viewed as nomothetic concepts. A student's understanding was determined by the conformity to a standard knowledge base. It was found upon or derived from custom or law. Yet in the constructivist point of view, student's conceptual frameworks are known as idiographic concepts. The evaluation of a student's knowledge depends on its own terms. The latter views the student's prior understanding as valuable and as an interpretive framework rather than as a barrier to learning. This made me emphasize students' prior concepts.

According to the generative learning model (Osborne & Wittrock, 1983), the teacher should be able to motivate students in restructuring concepts actively and providing appropriate guidance. Andre (1979) argued that questions, especially higher order ones, can promote students in making connections among idiographic concepts and new knowledge. Holliday and McGuire (1992) suggested a selective model: the questions asked can selectively focus students on specific concepts. Thus undergo a process of perception, association, restructuring, subsumption and, integration. To elicit students' understanding effectively, the designed tasks were

problem-centered.

III. Research method

Since four units had been conducted during past four years, thus each topic was taught to 2-5 classes of 7th graders. The average size of the classes was forty-five students.

Each unit covered for about 2 weeks. Several researcher-developed paper-and-pencil achievement tests were administered before and after the instructions to probe students' conceptual change presented in problem situations.

The classes were videotaped. 3-5 students were selected for in-depth interviews before and after each topic.

Some scales were used to probe students' conceptual understanding. Those were worksheets, student journals, teacher journals, videotape transcripts, and interview transcripts. The students were surveyed about their attitudes toward science before, during, and after the instructions.

Students' alternative conceptions determined from both written tests and interviews were cross-examined and synthesized in order to identify students' alternative frameworks.

The instruction procedures are:

- (1) Teacher's instructions. I introduced the topic, gave directions, motivated students, and confirmed students' understanding to the tasks.
- (2) Group discussion. The students played the following roles in turns: a facilitator was in charge of all works; a timekeeper watched the time; an inspector maintained order and discipline; an observer kept records of the interactions among group members; a recorder wrote down discussion results; and a reporter prepared to present the results.
- (3) Whole-class discussion. The reporter of each group presented results on a voluntary base. The students in other groups could refute, critique, or comment on the

presentation. I gave bonus points to the groups that presented their ideas.

- (4) Teacher's evaluation. I selected students from each group to answer task-related questions. The performance of the individual student represented the performance of the whole group. I identified members' contributions by individualized test or randomized questioning.
- (5) Students' self-evaluation. Students assessed their own learning and looked for ways of making improvement.

This research was based on the four steps of Feldman (1984): planing, acting, observing and, reflecting. The instruction procedures were revised more or less after every administration.

IV. Findings

1. Students showed positive attitudes toward cooperative learning.

From questionnaires after teaching, it was discovered that 96.1% of the students showed a positive attitude toward the pedagogical instruction. They paid more attention and spent more out-of-class time on the task. 95% of the students valued cooperative learning. 89% of the students considered the outcomes of their learning better than before. The students were not worried about the risk of grade decreasing.

The following is excerpted from students' journals:

Huang: The discussion questions are interesting. All the members were involved in the discussion, even during the ten-minute break.

Chang: I was interested! Those who used to fall asleep or chat with others were all interested too.

Tsai: I want to know more about this topic. Please give us more supplementary readings.

Lin: The questions are easy to understand. And the topic is daily life related.

Yu: The teacher praised us about the rich information covered. That makes us learn from listening and organizing information rather than memorizing facts.

Lai: The presentations today were rich in variety. Instead of studying for the tests, the learning is extended to the out of class activities.

From the teacher's observation, survey, and videotape transcripts, it was discovered that more than 80% of the students speak at a proper voice level, cooperate with each other, focus on the tasks, and speak out actively. However, only 50% of the students finished on time. Besides, 90% of the students were concentrated on the tasks, and showed respects to others' opinions during presentation as well as during whole class discussion. However, from the teacher's as well as students' observation checklists, It was found that the fluency, brief, accuracy, and richness of the presentations were scored about 40%. Less than 20% of the students exhibited their creativity in presentations.

From the student observation checklists, it was found that the interactions among students were not even. In students' self-evaluation sections, the students reflected about: the time of discussion isn't enough, the reporter's presentation was inaudible, stage fright, and students talking time is not distributed evenly.

2. Students' understanding about the nature of science was increased.

In regarding to the students' understanding of the nature

of science, it was discovered that before the instructions, 77.8% of the students thought that the scientific knowledge was accurate and unchangeable. They were brainwashed that "science is the only truth" and "the textbook has the only correct answer." The students considered the statements composed of scientific terms, such as molecules, atoms, elements, chemical reactions, carnivorous, herbivorous, thermostat, viviparous, as "scientific" and seldom thought of the meanings. There were some evidences from students' questionnaire before using constructivist teaching approach.

Tsai: The item stating that "The elements of the air synthesize into living objects under the action of the solar radiation" is considered as scientific. Because I think that the term "elements" is usually used in scientific areas, therefore, it must be scientific. (survey)

Su: Science progresses fast. We can read the books and know how the living organisms evolved. (survey)

Huang: My teacher in primary school told me that human beings evolved from monkey. The teacher should be always right, so does the textbook. (interview)

Duan: "Animals are classified into carnivorous and herbivorous." This statement is considered as scientific, therefore, it should be right. (interview)

Chang: Viviparous animals are in mammalian, platypus is not a viviparous animal, it should not be in mammalian.

Teacher: Platypus nurse the babies as human beings do.

Chang: It is not important that they nurse the babies or not, the standards such as viviparous or oviparous are more scientific.

After the instructions, students changed their attitudes. They learned that there are various theories besides that

stated in the textbook. They also learned to think critically about the theories. 80% of the students argued that there is no scientific knowledge that's absolutely right. They indicated that the reasons switched from scientific authority (64.5%) toward the limitations, relativity, and the variance of human cognition (68.9%). Besides this, students showed strong interests in knowledge from other resources:

Tsai: Scientific theories are changeable. The answer could be unexpectedly interesting while trying to explore it.
(journal)

Chen: It is difficult to find the answer. A theory can be refuted by new evidences. For example, the evolution theory is under modification. The knowledge in textbooks could be out-of-date. (journal)

Lee: There are various ways to explain the origin of life. We got some evidences but they are not enough to prove any theory. We can not dispose or believe in a certain theory without sufficient amount of evidences. (survey)

Chang: The classification scheme is not fixed. We can use a various of schemes to classify living things. The textbook is not always right. (interview)

3. Students' prior concepts were not always changed effectively.

The concepts of vertebrates. The results of the pre-and-post test of animal classification indicate: that the percentage of students who classify animals based on their habits is decreased from 48.9% to 6.7%. Such as classifying earthworms, centipedes, snails, ants as reptilian. The percentage of students with alternative conceptions generated from the common names of animals was decreased from 57.8% to 11.1%, such as classifying a seahorse as mammalian, and a whale

as Pisces. The percentage of the students who agreed in classifying animals based on their structures was increased from 44.4% to 95.6%.

The concepts of origins of species. The findings of this study indicate that learning evolution through discussion is challenging to their alternative conceptions of the nature of science, and is helpful to increase students' motivation in biology. Though, there is no evident change in their conceptions of genesis.

Huang: In the evolution unit, I learned about weaknesses of Darwin's theory of evolution. I now understand that there are several theories that might explain better in some aspects. But, I still prefer Darwin's theory of evolution. (survey)

Wong: I believe in out-of-space creatures. It is reported in newspaper. I like this kind of idea. (interview)

Teacher: Most of your classmates argued against this explanation. They thought it is not proved yet, as it is nonscientific. What's your opinion about this?

Wong: I am on the side of out-of-space creatures. It makes fewer mistakes as shown in evolution theory. Besides, it got some evidences, too. So it is a scientific explanation. (interview)

Huang: The evolution theory is wrong. I am for the creationism.

Teacher: Well. Many of your classmates were against creationism. Say it is not provable by conducting investigations, and it is not scientific if attributing to the God. What do you think?

Huang: In my opinion, science and religion are not at the opposite ends. I believe in that God creates living things.

Teacher: Why?

Huang: There is an experiment proved that amino acids can not synthesize a cell automatically. There must be a force that combines them. The Bible says God creates things.

I read from a book that claims the fossil evidences are against evolution theory and support for what described in the Genesis.

Teacher: Are you a Christian?

Huang: Yes.

Teacher: Then, if there is a new evidence that supports evolution theory, what will you do?

Huang: The new evidence is not necessarily right. I will still believe in God. (interview)

Chang read from books and got the similar idea with that in the textbook about the origin of species. After the unit, he remained his concepts intact and thought Darwin's idea as a popular idea. (teacher journal)

Lin watched cartoons about the creationism. This made her believe in creationism. She had no idea about other explanations before the instructions. After the unit, she can give a better description of various explanations, but that did not change her position for Creationism. (teacher journal)

V. Concluding Remarks

The findings were in accordance with the strengths of cooperative learning environment that Johnson and Johnson (1984) pointed out. The students were excited and actively participated in the group works. Under the cooperative learning context, I showed respects to the students' ways in constructing knowledge. The students were empowered to make choices, thus, become more responsible and motivated about learning. This diminished the time I spent on disciplinary problems.

Lazarowitz & Karsenty (1990), Watson (1991) reported that students' communication ability was increased and this agrees with the discoveries in the study. On the other hand, while

I got rid of an authoritative controlling role, the inter-relationship between students and me were highly improved.

After I adopted a constructivist teaching approach, the most significant changes of the students were their understanding about the nature of science.

The school curriculum has impacts on students' attitudes toward science, particularly on the controversial topics such as evolution and classification. Considering the constructs of constructivism, the characteristics of a scientific inquiry are such as: "science is a synthesis of logical reasoning and imagination," and "science is not authoritative." These guided me to help the students reason the issues in a flexible way.

In regarding to the origin of species, it is a matter of world-view and value. It is difficult to change students' ideas about these kinds of topics in only two classes. The objectives in this unit were to elicit students' ideas, figure out the problems the students have while they learn Darwin's theory, and help them clarify the concepts instead of imposing a theory on the students.

By providing students opportunities to have a debate on the classification scheme, 68.9% of students agreed that the classification scheme is an imposed creation on the nature by scientists. It is logical but not an absolute truth. In other words, the students now switched from an absolute point of view to a rather relative one.

By adopting this instruction approach, the students' prior concepts might not always change effectively, but it was helpful in challenging students' myths about science. Students can learn to think independently, reconsider their understanding, and construct concepts actively.

Humphreys, Johnson, & Johnson (1982) claimed that cooperative learning strategies have immediate as well as long-term effects on students' learning. This study also confirms the findings that in less controversial topics such

as nerve system and human circulatory system, students learned facts, information, concepts, principles, and theories more effectively. In addition to this, students' higher order thinking and critical thinking ability were also improved. It is worthwhile to develop instruction strategies to help students restructure their tolerable prior concepts.

VI. Suggestions

As teachers we do not just act as the gateway to knowledge. We ourselves represent, embody our curriculum. And, in our teaching, we convey not just our explicit knowledge, but also our position towards it, the personal ramifications and implication which it has for us.
Salmon (1988,p.42)

Since I heard about constructivism during the summer sessions of graduate courses, I have been changed a lot either in biology teaching method or my own conceptions of the nature of science as well as human cognition. As a researcher, I could not but examine the rationales and implementation strategies that I used to adopted and, that I was going to use. This impacted me to turn my traditional lectures into cooperative learning.

Most long-term influences of pedagogical reforms come from the inner heart instead of the brain. That is, the knowledge of teaching strategies must be planted on the in-depth reception of rationales.

After spending time immersing into constructivism, was the action research. The involved activities strengthen me as a proponent of constructivist cooperative learning.

It is valuable to provide in-service teachers with better understanding of pedagogical theories. In addition, the notion of "teachers as researchers" is also effective.

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Appendix

Task of "Vertebrates" Unit

The biology teacher nicknames the forty-five students in a 7th grade class in Chang-Der Junior High School. This makes the class a virtual zoo.

(1)monkey (2)lungfish (3)centipede (4)goat
(5)penguin (6)pangolin (7)wiggler (8)globe-fish
(9)crocodile (10)echidna (11)Trimeresurus Gramineus
(12)ichthyosaur (13)skate (14)squid (15)turkey
(16)hynobiidae (17)Tyrannosaurus rex (18)toad
(19)archaeopteryx (20)owl (21)pheasant
(22)tantu fish (Periophthalmus cantonensis)
(23)guineafowl (24)trionychidae (25)lizard (26)whale
(27)locust (28)loach (29)frog (30)proteidae
(31)octopus (32)platypus (33)green turtle (34)sea horse
(35)salamander (36)shark (37)tadpole (38)goose
(39)giant salamander (40)bat (41)silkworm (42)earthworm
(43)lamprey (44)ostrich (45)kangaroo

The teacher labeled the tables as: **Pisces, Amphibian, Reptilian, Birds, Mammalian, and others.** Please figure out your group and discuss with your group members about your common characteristics and habits. (Those who belong to "others" should discuss about why you are not in the previous five groups)

Can you figure out where you belong to quickly? How do you make the judgment? Please give others a rich description of yourself. **Good luck!**